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Interaction of swine nursery and grow-finish space allocations on performance[1]

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ABSTRACT: Two experiments were conducted to evaluate the possible interaction of nursery space allocations and grow-finish space allocations in swine. In Exp. 1, crowding was achieved by varying the number of pigs per pen. During the nursery phase, decreasing the space allocation (0.16 m^2/pig vs 0.25 m^2/pig; 8 and 12 pens per treatment, respectively) by increasing the number of pigs per pen (18 vs 12) resulted in a decrease in daily feed intake (0.609 vs 0.683 kg/d; $P < 0.001$) and daily gain (0.364 vs 0.408 kg/d; $P < 0.001$). Pigs were mixed within nursery treatment groups and reassigned to grow-finish pens (6 pens per treatment) at the end of the 35-d nursery period providing either 0.56 m^2/pig (14 pigs/pen) or 0.78 m^2/pig (10 pigs/pen). Crowding during the grow-finish phase decreased daily feed intake ($P < 0.003$) and daily gain ($P < 0.001$). In Exp. 2, space allocations of 0.16 m^2/pig vs 0.23 m^2/pig during the nursery phase (24 pens per treatment) resulted in a decrease in daily feed intake (0.612 vs 0.654 kg/d; $P < 0.005$) and daily gain (0.403 vs 0.430 kg/d; $P < 0.001$). Pigs remained in the same (social) groups when moved to the grow-finish phase. Unlike Exp. 1, there was no effect of crowding during the grow-finish phase (0.60 m^2/pig vs 0.74 m^2/pig) on daily feed intake or daily gain. The difference in results between experiments suggests that the response to crowding during the grow-finish phase may depend in part on whether pigs are mixed and sorted following movement from the nursery.

Key Words: Mixing, Pigs, Spacing

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Introduction

The impact of space allocation during the nursery phase and grow-finish phases of production has been well documented (Gehlbach et al., 1966; Kornegay and Notter, 1984; NCR-89 Committee on Confinement Management of Swine, 1993) with results indicating that a decrease in space allocation within each phase of production decreased daily feed intake and daily gain in a consistent manner. The impact on feed conversion efficiency is less predictable.

More recent research has focused on the economic consequences of space allocation during the grow-finish phase (Powell and Brumm, 1992). In addition, it is clear that the decrease in daily gain associated with the decrease in daily feed intake cannot be overcome by increasing the nutrient density of the diet (Kornegay et al., 1993; Brumm and Miller, 1996; Edmonds, et al., 1998), nor do pigs given less space respond differently to growth-promoting feed additives than pigs allowed recommended space (Zimmerman, 1986).

In all of the space allocation trials cited, the effects of space allocation were investigated during either the nursery or grow-finish phases of production. There has been no published data on the possible interaction of space restriction during the nursery phase on the response to space restriction during the growing-finishing phase. Therefore, two experiments were conducted to determine the effect of space allowance during the nursery phase and space allowance during the grow-finish phase on pig performance from weaning to slaughter. In the first experiment, pigs within space treatments were reallotted (mixed) between the nursery and grow-finish periods. In Exp. 2, pigs remained in their pen

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groups (no mixing) between nursery and grow-finish periods.

Materials and Methods

Experiment 1

In each of two trials, 144 mixed-sex crossbred pigs were purchased at weaning (24 d of age) and transported 20 km to the University of Nebraska's Haskell Agricultural Laboratory, at Concord, within 2 h of weaning. Immediately after arrival, all pigs were weighed, ear-tagged, and assigned to experimental treatments on the basis of sex and BW outcome groups (light or heavy BW).

In the nursery phase, the pigs were housed in a mechanically ventilated, two-room nursery facility (Brumm, et al., 1985). There was one weight block per room (weight block confounded with nursery room). Within each room there were five 1.22- × 2.44-m pens. There were three pens of 12 pigs/pen (0.25 m^2/pig; **Uncrowded** and two pens of 18 pigs/pen (0.16 m^2/pig; **Crowded**) per room, for a total of 12 Uncrowded and 8 Crowded pens. Each pen had two nipple drinkers and one feeder space for every two pigs. Pen size was not adjusted in the event of pig death or removal.

For the first week after weaning, air temperature in the pig zone was maintained at 30°C. Beginning 1 wk after weaning, thermostat settings were decreased 2°C/wk. From 1900 to 0700, thermostat settings were decreased an additional 6°C based on the recommendation of Brumm and Shelton (1988).

After the 5-wk nursery period, all pigs were moved to a partially slatted, fan-ventilated growing-finishing facility. Within crowded and uncrowded nursery treatments, pigs were blocked by weight and sex into three groups and were randomly assigned by sex within weight group to the growing-finishing space allocations of either 10 (uncrowded grow-finish, **Uncrowded-GF**) or 14 (crowded grow-finish, **Crowded-GF**) pigs per 1.8- × 4.6-m pen (0.78 vs 0.56 m^2/pig when allowance is made for feeder) for a total of four grow-finish treatments.

Each growing-finishing pen had one nipple drinker and three feeder holes. Water sprinklers were provided for summer heat relief (> 27°C) and pen sizes were not adjusted if a pig died or was removed for substandard performance (two consecutive weighings of less than 0.2 kg/d daily gain).

On the week when individual pigs weighed 104.5 kg or greater, they were removed for slaughter. Estimates of carcass lean were collected on individually identified pigs by employees of SiouxPreme Packing Co., Sioux Center, IA, using total body electrical conductivity. Data were reported as carcass percentage lean containing 5% fat. Lean gain containing 5% fat was calculated using the procedures of NPPC (1991).

At weaning, all pigs were offered a commercial, pelleted diet containing 1.4% lysine (Carl Akey Inc., Lewisburg, OH) until the week when the average weight of all pigs within a pen was 10.5 kg or greater. They were then offered a 1.15% lysine diet formulated with corn-soybean meal, and 3% added fat for the duration of the nursery phase. During the growing-finishing phase, the corn-soybean meal-based diets were fed in meal form, contained 3% added fat, and were formulated to contain 0.9% lysine to 41 kg BW, 0.8% lysine from 41 to 82 kg BW, and 0.7% lysine from 82 kg BW to slaughter.

Nursery diets contained 100 mg of oxytetracycline/kg and 154 mg of neomycin/kg. Grower-finisher diets contained 44 mg of tylosin/kg. All diets met or exceeded NRC (1988) requirements for vitamins and minerals.

Experiment 2

In each of five cooperating experiment stations in the North Central region of the United States (Table 1), pigs at weaning were assigned to one of four (2 × 2 factorial arrangement) nursery/grow-finish space allocation treatments on the basis of sex and weight outcome groups. Sex was balanced within pens within weight outcome groups.

Within station, nursery pen size was constant with the space allocations of 0.16 (Crowded) and 0.23 (Uncrowded) m^2/pig achieved by varying the number of pigs per pen except Minnesota, which varied pen size. Pen size was adjusted in the event of pig death or removal for substandard performance. There was at least one feeder hole for every two pigs and one nipple drinker for every 10 pigs.

Table 1. Cooperating stations and replications (Exp. 2)

Station	No. of replicates	Weaning		Pigs/pen				Genetics[b] (sire × dam)
		Age, d	Wt, kg	Crowded	Uncrowded	Crowded-GF	Uncrowded-GF	
Illinois	3	21	4.8	9	6	9	6	PIC (326 × C15)
Iowa	3	17	5.9	8	6	8	6	HD × YL
Michigan	2	30	7.3	15	10	9	9	Newsham × YL
Minnesota	2	18	5.1	11	11	11	9	H × YL
Nebraska	2	15	4.0	18	12	18	12	PIC (326 × C15)

[a]Crowded = 0.16 m^2/pig nursery; Uncrowded = 0.23 m^2/pig nursery; Crowded-GF = 0.60 m^2/pig grow-finish; Uncrowded-GF = 0.74 m^2/pig grow-finish.
[b]PIC = PIC Inc., Franklin, KY; H = Hampshire; D = Duroc; Y = Yorkshire; L = Landrace; Newsham = Newsham Hybrids (USA), Colorado Springs, CO.

Table 2. Effect of space allocation on nursery performance, least squares means (Exp. 1)

Item	Treatment[a] Crowded	Uncrowded	*P*-value
No. of pens	8	12	
Pig weight, kg			
Initial	6.6 (<0.1)[b]	6.6 (<0.1)	
Final	19.4 (0.3)	20.9 (0.2)	0.0005
CV of within-pen weight, %[c]	13.7 (1.0)	12.1 (0.8)	0.234
Average daily gain, kg	0.364 (0.007)	0.408 (0.006)	<0.0005
Average daily feed, kg	0.609 (0.012)	0.683 (0.009)	<0.0005
Gain:feed, kg/kg	0.602 (0.007)	0.601 (0.006)	0.910
Pigs dead or removed, %	0.0	0.7	

[a]Crowded = 0.16 m^2/pig (18 pigs/pen); Uncrowded = 0.25 m^2/pig (12 pigs/pen).
[b]Values in parenthesis are standard errors.
[c]Coefficient of variation of within-pen weight at final weight.

On the week when the average weight of pigs in the pen assigned to the Uncrowded treatment was 20.5 kg or greater within a weight replicate, all pens within the replicate were moved to the growing-finishing facilities as intact pens. Unlike Exp. 1, there was no sorting or remixing of pigs.

The grow-finish facilities provided either 0.60 m^2/pig (Crowded-GF) or 0.74 m^2/pig (Uncrowded-GF). To achieve correct grow-finishing stocking densities, the Minnesota and Michigan stations removed pigs from each pen randomly identified at the time of initial allocation. All other stations maintained pen-group integrity with the move.

There was at least one feeder space per five pigs and one nipple drinker per 15 pigs during the growing-finishing phase. In the event of pig death or removal for substandard performance, pen size was adjusted. Water sprinklers were used for summer heat relief at all stations except Minnesota. Stations with partially slatted facilities maintained the same solid:slat ratio in both treatments.

Individual pigs were removed for slaughter on the week they weighed 109 kg or greater. On the week when 50% or more of the pigs within a pen (based on the number of pigs in the pen when the first pig was removed for slaughter) were removed, the remainder were held as a group with no further removal until either the average weight of the remaining pigs was 109 kg or until 3 wk had elapsed. Pen size was not adjusted once pigs were removed for slaughter. Carcass data were gathered on all pigs that weighed at least 100 kg at slaughter.

Diets during the grow-finish phase were formulated with corn-soybean meal and no added fat. Lysine concentrations were based on the estimated genetic potential within station (Table 1) and growth promoting feed additives were used according to each participating station's normal protocol.

Carcass lean content was estimated either on individually identified pigs sent to commercial slaughter houses (Iowa, Minnesota, and Nebraska) or by a NSIF (National Swine Improvement Federation, Raleigh, NC) certified technician using real-time ultrasound scan (Michigan and Illinois). Lean gain during the grow-finish phase containing 5% fat was calculated using the procedures of NPPC (1991).

Statistical Analysis

The pen of pigs was considered the experimental unit for statistical analysis in both experiments. Analyses of variance as a randomized complete block design were conducted using the GLM procedures of SAS (SAS Inst., Inc., Cary, NC). In Exp. 1, the nursery and grow-finish phases were analyzed separately because of the confounding caused by the mixing of pigs at the end of the nursery phase. The model for nursery performance included weight block (room), treatment, trial, and two- and three-way interactions. The model for grow-finish performance included nursery treatment, grow-finish treatment, trial, and two- and three-way interactions. Single degree of freedom contrasts were used to test treatment effects. The contrasts were 1) Crowded/Crowded-GF + Crowded/Uncrowded-GF vs Uncrowded/Uncrowded-GF + Uncrowded/Uncrowded-GF to examine for a nursery space allocation carryover effect; 2) Crowded/Crowded-GF + Uncrowded/Crowded-GF vs Uncrowded/Uncrowded-GF + Crowded/Uncrowded-GF to examine the main effect of grow-finish space allocation; and 3) Crowded/Crowded-GF + Uncrowded/Uncrowded-GF vs Crowded/Uncrowded-GF + Uncrowded/Crowded-GF to examine the interaction between nursery and grow-finish space allocation.

In Exp. 2, the error mean square of the station × treatment interaction was used as the error term to test treatment effects, and the treatment × replication within station error mean square was used to test the station × treatment interaction.

The percentage of pigs that died or that were removed in each experiment were analyzed by chi square analysis.

Table 3. Effect of space allocation on grow-finish performance (Exp. 1)

Item	Treatment[a] CNCGF (1)	CNUGF (2)	UNCGF (3)	UNUGF (4)	SE	Contrasts 1+2 vs 3+4	1+3 vs 2+4	1+4 vs 2+3
No. of pens	6	6	6	6				
Pig weight, kg								
Initial	19.4	19.4	21.0	21.0	0.2	0.0001	0.982	0.822
Final	109.7	110.2	107.8	111.3	0.5	0.466	0.0015	0.010
CV of within-pen weight, %[b]	8.4	9.6	8.7	6.9	0.9	0.179	0.747	0.117
Average daily gain, kg	0.817	0.849	0.781	0.867	0.011	0.443	0.0001	0.029
Average daily feed intake, kg	2.533	2.589	2.465	2.665	0.034	0.912	0.0023	0.055
Gain:feed, kg/kg	0.323	0.328	0.318	0.326	0.004	0.377	0.126	0.783
Carcass % lean[c]	47.7	46.3	47.8	46.3	0.3	0.869	0.003	0.899
Average daily lean gain, kg[c]	0.298	0.299	0.286	0.304	0.005	0.541	0.100	0.135
Pigs dead or removed, %	3.6	1.2	5.0	5.0				

[a]CNCGF = 0.16 m^2/pig nursery, 0.56 m^2/pig grow-finish; CNUGF = 0.16 m^2/pig nursery, 0.78 m^2/pig grow-finish; UNCGF = 0.25 m^2/pig nursery; 0.56 m^2/pig grow-finish; UNUGF = 0.25 m^2/pig nursery, 0.78 m^2/pig grow-finish.
[b]Coefficient of variation of pig weight within a pen when the first pig was removed for slaughter.
[c]Containing 5% fat.

Results and Discussion

Experiment 1

Results of the nursery phase of Exp. 1 are presented in Table 2. Because there was no trial × treatment interaction, the results are presented for the main effects of space allocation. Similar to previous reports (Kornegay and Notter, 1984; Spicer and Aherne, 1987; Kornegay et al., 1993), putting more pigs in a nursery pen, resulting in less space per pig and more pigs per social group, resulted in decreased feed intake ($P < 0.001$), decreased daily gain ($P < 0.001$) and a 1.5-kg lighter pig at 35 d postweaning. There was no effect of nursery treatment on weight variation within a pen, feed conversion efficiency, or the number of pigs that died or were removed for poor performance during the nursery phase.

Results of the growing-finishing phase of Exp. 1 are presented in Table 3. Similar to the nursery phase, there were no trial × treatment interactions. There was no residual effect of nursery crowding on grow-finish performance. However, crowding in the grow-finish phase resulted in a decrease in daily feed intake ($P < 0.003$), daily gain ($P < 0.001$), carcass lean percentage ($P < 0.003$), and daily lean gain ($P = 0.10$). There was no effect of crowding on gain:feed or variation in weight within the pen when the first pig was marketed.

The response to grow-finish crowding was affected by the nursery crowding treatment that the pigs experienced. Pigs that were uncrowded during the nursery phase and crowded in the grow-finish phase had a lower feed intake and daily gain than pigs that were crowded in both the nursery and grow-finish period. The response to crowding during the grow-finish phase was more evident for pigs that were uncrowded vs crowded during the nursery period. There was no effect of grow-finish space allocation on feed conversion efficiency.

Experiment 2

In Exp. 1, new social groups were established within nursery treatment groups when the pigs were re-ran-

Table 4. Effect of space allocation on nursery performance (Exp. 2)

Item	Treatment[a] Crowded	Uncrowded	SE	P-value
No. of pens	24	24		
Pig weight, kg				
Initial	5.4	5.4	0.1	
Final	21.4	22.7	0.3	0.001
CV within pen weight, %[b]	13.0	11.5	1.4	0.472
Average daily gain, kg	0.403	0.430	0.007	0.001
Average daily feed intake, kg	0.612	0.654	0.015	0.005
Gain:feed, kg/kg	0.663	0.659	0.014	0.821
Pigs dead or removed, %	1.4	1.5		

[a]Crowded = 0.16 m^2/pig; Uncrowded = 0.23 m^2/pig
[b]Coefficient of variation of within pen weight at time of removal from nursery.

Table 5. Effect of space allocation on grow-finish performance (Exp. 2)

Item	CNCGF	CNUGF	UNCGF	UNUGF	SE
	Treatment[a]				
No. of pens	12	12	12	12	—
Pig weight, kg					
From nursery	21.4	21.1	22.3	22.5	0.3
Final	109.5	108.0	110.7	111.0	0.6
CV of within-pen weight, %[b,c]	9.4	10.4	9.4	8.5	0.3
Average daily gain, kg	0.821	0.821	0.827	0.831	0.007
Average daily feed intake, kg	2.386	2.419	2.398	2.433	0.023
Gain:feed, kg/kg	0.344	0.340	0.345	0.342	0.003
Carcass % lean[d]	52.3	51.5	52.4	52.2	0.2
Lean gain, kg/d[d]	0.338	0.332	0.331	0.336	0.003
Pigs dead or removed, %	0.4	0.4	1.0	1.0	—

[a]CNCGF = 0.16 m^2/pig nursery and 0.60 m^2/pig grow-finish; CNUGF = 0.16 m^2/pig nursery and 0.74 m^2/pig grow-finish; UNCGF = 0.23 m^2/pig nursery and 0.60 m^2/pig grow-finish; UNUGF = 0.23 m^2/pig nursery and 0.74 m^2/pig grow-finish.
[b]Coefficient of variation of within-pen weight when first pig removed for slaughter.
[c]Interaction of nursery × grow-finish space allocation ($P < 0.05$).
[d]Containing 5% fat.

domized upon movement to the grow-finish facility. To remove this possible confounding, Exp. 2 was designed to maintain social group integrity during the move from nursery to grower-finisher.

Similar to responses in Exp. 1, at the end of the nursery phase, uncrowded nursery pigs were heavier ($P < 0.001$) than crowded pigs, because of a higher feed intake ($P < 0.005$) and daily gain ($P < 0.001$) (Table 4). There was no effect of space allocation on the uniformity of weight within the pen, gain:feed ratio, or number of pigs that died or were removed for poor performance.

Unlike responses in Exp. 1, there were no effects of grow-finish space allocation on daily gain, daily feed intake, lean gain, or feed conversion efficiency (Table 5). There were also no interactions ($P > 0.1$) between nursery and grow-finish allocation on any performance trait reported, except for variation in BW within the pen when the first pig was removed for slaughter.

When pig performance from weaning to slaughter was examined (Table 6), greater daily gain during the nursery phase for the uncrowded-nursery treatment resulted in a greater rate of gain ($P < 0.01$) from weaning to slaughter, regardless of the grow-finish space allocation. This faster gain was associated with a higher ($P < 0.05$) feed intake for the uncrowded compared with the crowded nursery treatment.

In both experiments, crowding (0.16 m^2/pig) decreased ADG and ADFI during the nursery period. However, in the grow-finish period, crowding (0.56 m^2/pig in Exp. 1 and 0.60 m^2/pig in Exp. 2) decreased ADG and ADFI only in Exp. 1. It is not clear why growth performance was not affected by crowding during the grow-finish period in Exp. 2. It is not likely that the small difference in space allowance between experiments (0.56 vs 0.60 m^2/pig) was responsible. It may be that keeping pigs in intact social groups from the time of weaning allows them to cope with crowding in the grow-finish period to a greater extent than pigs that are mixed at the beginning of the grow-finish period. It would seem, however, that pigs would have ample time to establish new social groups at the early part of the grow-finish period when space (0.56 m^2/pig) should not limit pig performance.

Moore et al. (1994) reported that more pigs were removed for poor health in frequently remixed social groups than in static groups. There is a body of evidence

Table 6. Effect of space allocation on performance from weaning to slaughter (Exp. 2)

Item	CNCGF	CNUGF	UNCGF	UNUGF	SE
	Treatment[a]				
Average daily gain, kg[b]	0.700	0.700	0.715	0.717	0.005
Average daily feed intake, kg[c]	1.873	1.867	1.906	1.925	0.013
Gain:feed[d], kg/kg	0.373	0.373	0.376	0.373	0.002

[a]CNCGF = 0.16 m^2/pig nursery and 0.60 m^2/pig grow-finish; CNUGF = 0.16 m^2/pig nursery and 0.74 m^2/pig grow-finish; UNCGF = 0.23 m^2/pig nursery and 0.60 m^2/pig grow-finish; UNUGF = 0.23 m^2/pig nursery, and 0.74 m^2/pig grow-finish.
[b]Contrast CN vs UN; $P < 0.01$.
[c]Contrast CN vs UN; $P < 0.05$.
[d]Nursery × grow-finish interaction ($P < 0.001$).

that suggests the increased aggression associated with mixing of pigs can lead to decreased growth (McGlone and Curtis, 1985; Stookey and Gonyou, 1994; Otten et al., 1999). O'Connell and Beattie (1999) have suggested that dominance characteristics are established early in life and remain stable through the growing period. Thus, it is quite possible that the lack of a depression in performance in Exp. 2 due to crowding during the grow-finish phase is related to the stable social order associated with not mixing pigs at the end of the nursery phase as was done in Exp. 1. The large body of research examining the effects of crowding on grow-finish pigs has all relied on experimental animals that were mixed and assigned to experimental treatments at the start of the grow-finish period (Kornegay and Notter, 1984; NCR-89, Committee on Confinement Management of Swine, 1993; Brumm and NCR-89, Committee on Confinement Management of Swine, 1996).

Implications

The lack of response to space restriction during the grow-finish phase of Exp. 2 vs the traditional response in Exp. 1 suggests that the response to space allocation may differ depending on how pigs are managed during the move from the nursery to the grower-finisher. Although the traditional literature on space allocation is based on reallocation of pigs into uniform sex and weight outcome groups at the beginning of an experiment, the results of Exp. 2 suggest that further research is warranted to define the role of this reallocation on the response. Many production systems maintain pen identity (no reallocation) between nursery and grow-finish phases of production and thus may not experience as dramatic an effect of space allocation as predicted by the literature.

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